

HISTORY OF A LANDFILL SITE NEAR LAS CRUCES, NM

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Abstract

The proper handling and characterization of past hazardous waste sites are becoming more and more important as world population extends into areas previously deemed undesirable. Historical photographs, past records, current aerial and satellite imagery, as well as GIS products can play an important role in characterizing these sites. These data provide clear insight into defining problem areas which can be surface sampled for further detail.

As a demonstration project, historical black and white, color, and infrared photography, as well as map products were scanned and coregistered to provide a non-intrusive characterization of the former Las Cruces Municipal Landfill. This landfill is located southwest of the city of Las Cruces, New Mexico. This site is in close proximity to the Rio Grande River and only a short elevation over the local water table. The landfill was closed a few years ago and there is concern about contaminant leakage into the Rio Grande.

Digital analysis of historical photography acquired from the Earth Data Analysis Center (EDAC) provided a preliminary characterization through change detection. Changes were mapped from 1947 through 1994. Biomass change mapping of coregistered, multirate, color infrared imagery helped reveal changes in biomass and plant vigor over time, a common anomaly found in and around waste areas. The change in plant health and abundance, either for the better or worse is a strong indicator of leachates and nonsource point pollution. Map based information such as soil, hydrology, and topography were fused with existing imagery to help assess potential contaminant routes from the site toward ground water areas and the Rio Grande.

Digitally analyzing and integrating historical imagery with map based information provided quick detection and mapping of obvious sources of contamination over time, as well as providing a probable migration tendency. An accurate and thorough characterization of the site by imagery techniques provides a safer and more cost effective field investigation, especially when designing drilling and soil sampling surveys. Once both surface and subsurface investigations are completed, a three dimensional model can be derived that would help visualize subsurface features such as contamination plumes near or in ground water.

Regional Description

Doña Ana County is in south-central New Mexico, bordering on El Paso County, Texas and the state of Chihuahua, Mexico (Fig. 1). The county region consists of gently sloping plains occasionally interrupted by rugged mountain ranges and the Rio Grande River. There are several mountain ranges in the area with a north-south orientation. The mountains nearest the Las Cruces study area are the East Potrillo mountains in the southwest, the Doña Ana mountains north of Las Cruces, and the Robledo Mountains, northwest of Las Cruces.

Elevation in the area varies. The mountains slopes are steep to extremely steep beginning at 5,600 feet and in places exceeding 7,000 feet. The Rio Grande Valley which passes between the rugged mountains is nearly flat to gently sloping. Elevations range from 3,700 feet to approximately 5,000 feet. The width of the valley varies from 1 to 5 miles. The Rio Grande drains the agricultural and commercial land immediately adjacent to it.

The climate conditions in Doña Ana County and specifically the Las Cruces area are very arid, except for some of the higher elevations. The average annual precipitation ranges uniformly across the county, from 1 to 9 inches . The summer months have the highest density of precipitation. Dust storms are frequent, mostly occurring in the spring and are due to sparse vegetation and dry sandy soils.

Las Cruces Description

The population of the city of Las Cruces is approximately 67,000, with a county population of 145,000. The elevation of the city is 3,900 feet above sea level and is comprised of desert fertile valleys, hills, and mountain ranges for terrain. A large portion of the land use east and southeast of Las Cruces is agricultural and consists of fields of chile, cotton, and groves of pecan trees, as well as acres of vineyards.

The temperatures ranges from 59/27 in January to 94/62 in July. Other months average 77/45 for the highs and lows. The annual average for sunshine is 350 days. Annual precipitation is eight inches. (University of New Mexico Web Site)

Figure 2 depicts the general terrain of the survey area. This graphic is a 1:250,000 Digital Elevation Model (DEM) merged with a georeferenced polygon vector representing the Rio Grande River. The vector was created using TNTmips (a commercial image processing software package) and the DEM was acquired from the USGS WEB site. The final DEM in Fig. 2 was created by merging an east and west DEM through a mosaic interpolation process inherent to TNTmips. The yellow lines comprise a vector file of all roads in the Las Cruces area.

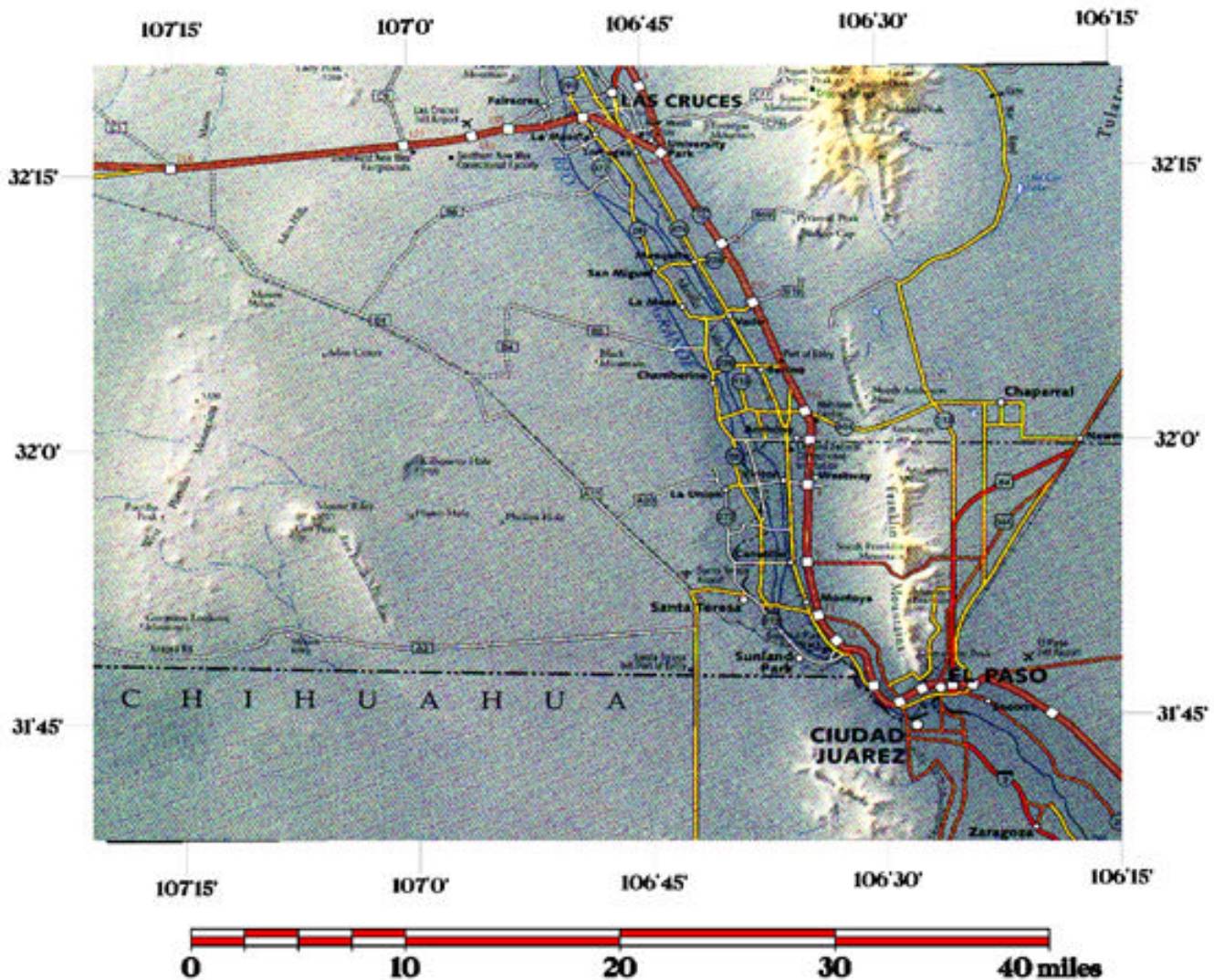


Fig. 1. Map of Las Cruces and the surrounding area.

Study Area

The landfill in Las Cruces, Doña Ana County came into existence before the EPA's strict standards of sanitary landfills. Aerial photographs dated as early as 1955 shows evidence of unregulated dumping. Since the landfill is so old, it does not have a liner and is most likely leaching contaminants into the fresh groundwater beneath it.

Contamination of groundwater and nearby surface water is a serious problem, especially for unlined and abandoned landfills. When rain filters through a landfill it leaches out water soluble dyes, metal compounds, and other toxic materials. This material seeps from the bottom of the unlined landfill into the local watershed. Soil samples should be collected in and around the watersheds fed by the landfill to determine the presence and concentrations of toxins. Several wells could be drilled strategically around the site to monitor the drainage of leachate (a minimum of 3).

Ground water contamination is only one side effect of unlined landfills. Since the landfill area is covered with dirt, organic wastes decompose anaerobically. Such underground decomposition of waste

produces many toxic and volatile gases such as hydrogen sulfide and methane gas. (Miller, 1994) The air quality in and around the Las Cruces landfill should be tested for the existence of such gases.

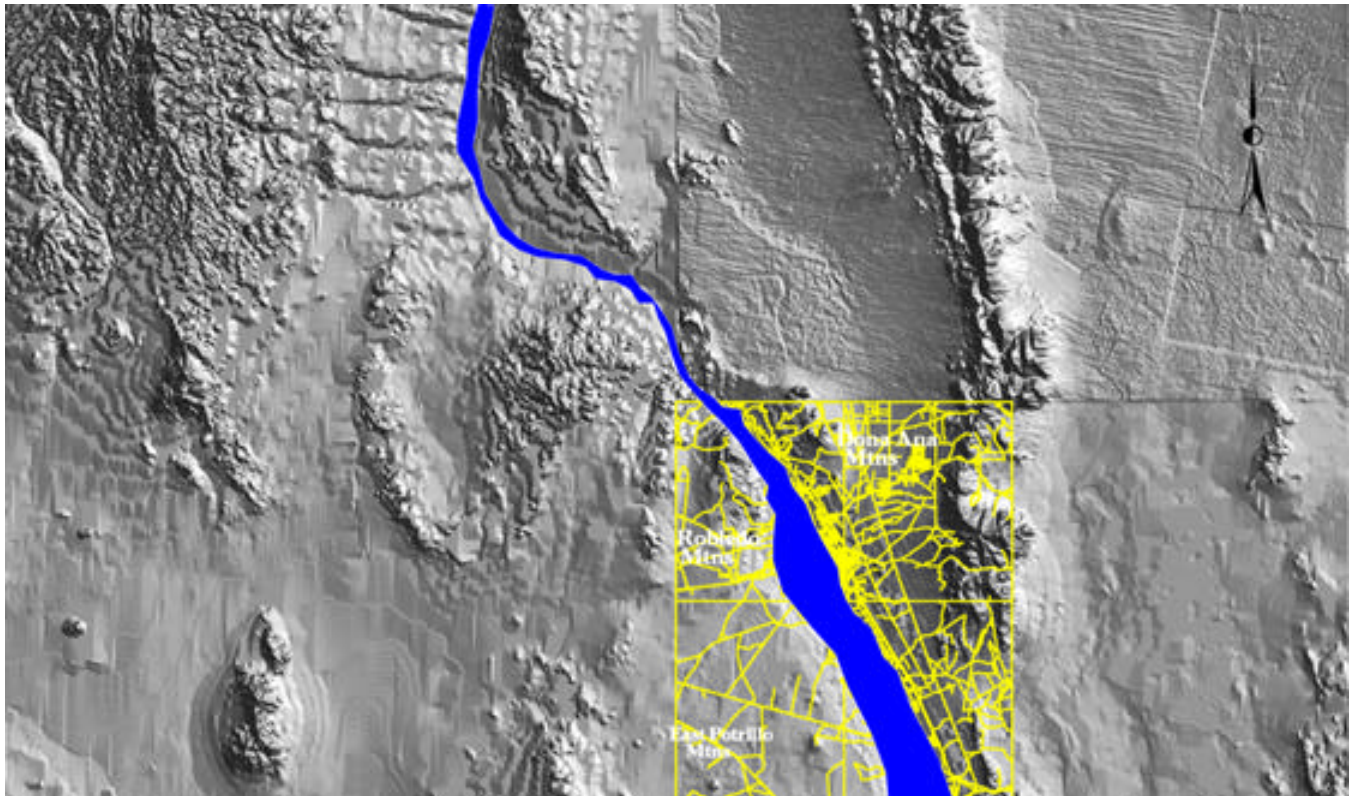


Fig. 2. Digital elevation model of Doña Ana County at 1:250,000 scale.

Data Preparation

Landfills can be easily identified and characterized on aerial photographs. Several multidecade, aerial photographs covering the Las Cruces landfill and surrounding area were collected. The coverage time line ranges from December of 1947 to April of 1994. The images were scanned at 600 dpi and included the site area which extends east to the Rio Grande, 0.25 miles beyond the western edge of the site, 0.5 miles beyond the northern edge, and 1 mile south of the southern most boundary. The resolutions varied from 1:20,000 to 1:40,000 ft.

The scanned images were imported as raw raster files into TNTmips. The images were georeferenced using Latitude and Longitude mapping projections. A normal contrast transformation was then applied. The transformation was done because the cell values of the original digitized images were not distributed across the entire data range. This normalization strengthens the visual contrast by pulling light gray values closer to white and dark gray values closer to black. The images were then used to make generalizations about the study area, as well as providing reference for vector generation containing topography, hydrography, hypsography, and roads.

Change Mapping

The multigate images were trimmed and exported as raw data files. These images were fed to a transformation process so they could be registered to a base image. In this study, the 1994 photo served as the master image. All the photos were vertical, requiring only rotation, scaling, and translation to match the master image. A program called MOTIFSHO was used to coregister, warp, and animate the site images. The coregistration and animation of multigate imagery provide an accurate time line analysis or change mapping of the site. As a direct result of the animation, a vector map was created which reveals the annual growth of the site from 1955 through June of 1994. Figures 3 and 4 describe that growth.

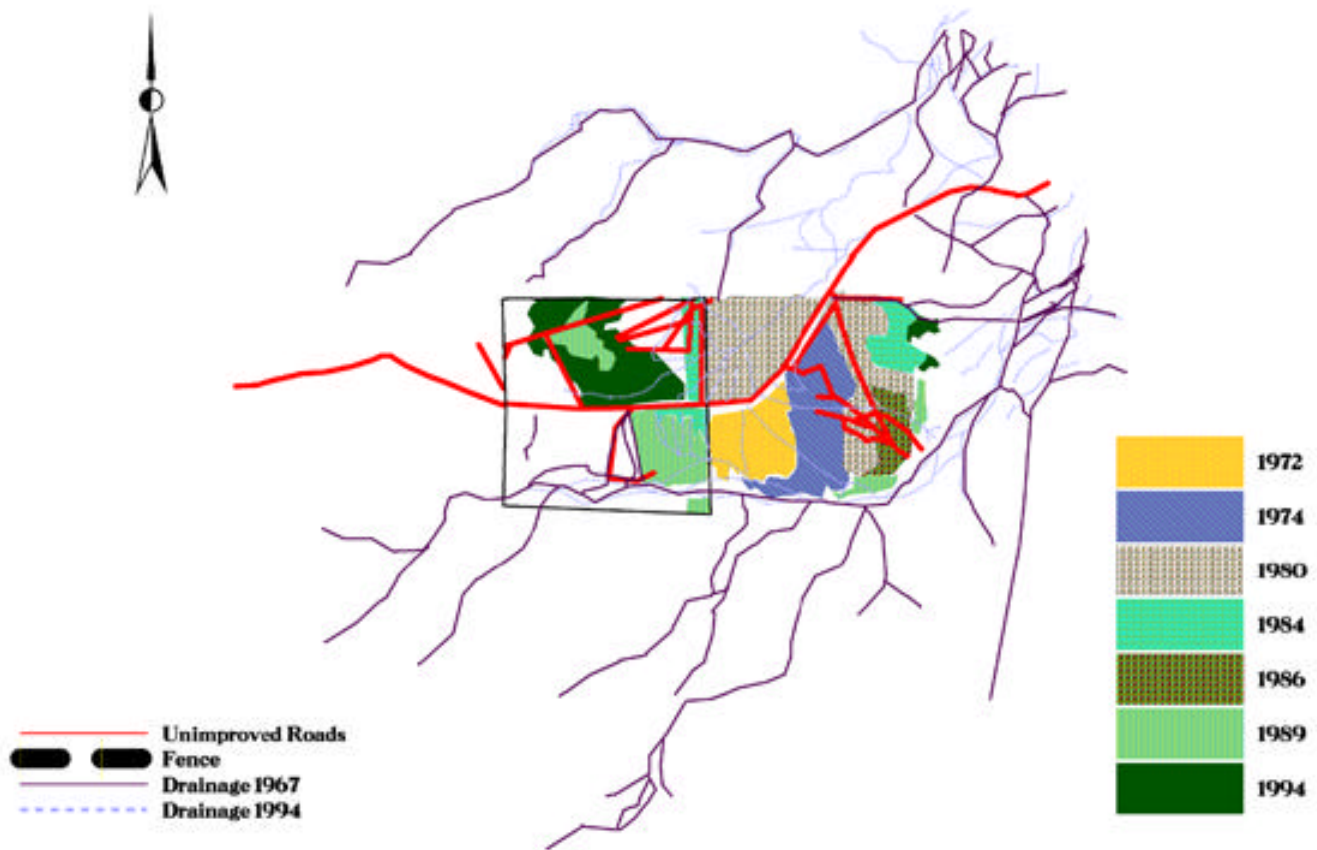


Fig. 3. Vector map created from animation of multigate imagery.

Landfill Physical Characteristics

Typical features used to identify the site include the following:

- 1.) Gross morphology (patterns foreign to the area),
- 2.) An access road through the middle of the site and extending to the outer limits of the site,
- 3.) A fence line surrounding the area with parallel access points,
- 4.) The obvious lack of vegetation and linearity in soil patterns, and
- 5.) Typical fan shape with square boundaries and ridges of cover material near the working face.

Identifying and tracking the transformed features of the landfill not only provided estimates of annual growth, but also provided clues to significant changes concerning topography. Some transformations are significant enough to change the behavior of the watershed. These modified areas are shown in Figs. 4 (a) through 4 (c).

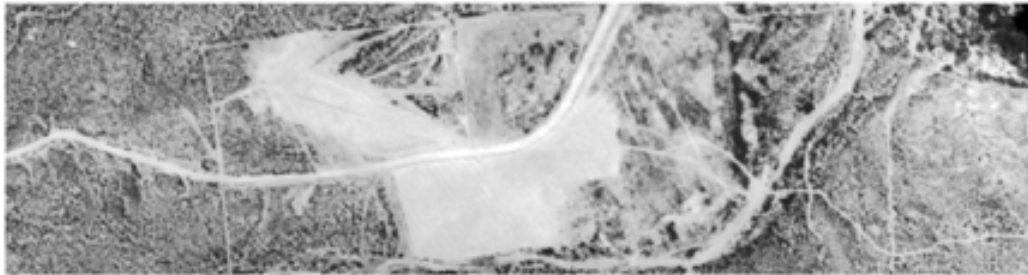


Fig. 4 (a) Gross morphology, 1994.



Fig. 4 (b) Fence line, 1989.

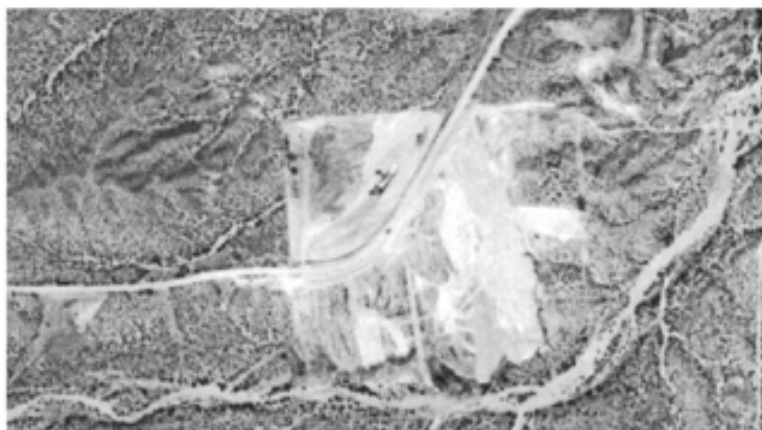


Fig. 4 (c) Fan shape, square boundaries, 1980.

Another identifying feature around landfills can be found in multispectral imagery. High albedo is associated with vegetation at the outermost edges of the site. The increased albedo results from material placed in the dump being blown around the site, eventually coming to rest on a tree or bush. Multispectral imagery was not provided for this analysis, but could be quite useful in characterizing the biomass of local vegetation, as well as chemicals present on or near the surface of the soil. (Bomberger, 1960)

The drainage texture ranges from fine to a medium texture at the landfill site. This implies that the soils and rocks in this area have poor internal drainage and high surface runoff. Another indicator of poor internal drainage is the gully shape found throughout the site photos. The gullies are generally "U" shaped suggesting the soil is silty or loamy.

The flow of surface water runoff from the site appears to originate from the freshly graded portions of the site, down average to steep embankments to a primary channel and eventually to the Rio Grande and its adjacent plains. Natural drainage from the site to the Rio Grande has increased slightly due to :

- 1.) removal of vegetation around the site reducing consumptive water loss,
- 2.) soil disturbance, leaving exposed bare rock or impermeable soil (high potential runoff), and
- 3.) some increased bank slopes.

Soil Study

A soil survey map and report was compiled for Doña Ana County, New Mexico by the State Department of Agriculture in cooperation with other government offices. The general soil upon which the landfill resides can be described as deep, well drained soils that formed in alluvium on flood plains and stream terraces. Areas east of the Rio Grande, to include the Rio Grande, consist of Pajarito-Onite-Pinture. Areas west of the Rio Grande, the site itself, contains Glendale-Harkey soil. Soil maps only provided a broad perspective of soils in the reported area. The Doña Ana County map is also on a very small scale, 1:443,500. It would be beneficial to have a soil map at a much larger scale.

Vegetation and Terrain

The agricultural cover consists specifically of row crops, field crops, groves, and vineyards. The shrub and brush rangeland cover consists of a wide range of plant communities, such as sagebrush, chaparral, and second-growth brush land (Anderson, 1976). Also note that the sage and brush land use immediately southwest of the city contains only one commercial use item, the landfill.

As previously mentioned, cultivated vegetation covers the plains east and adjacent to the Rio Grande. Since most of the fields are being farmed, it is safe to assume that these soils are organic in nature and commonly not well drained.

Water Table Surface Map

The Mesilla Valley water table is 10-25 feet below land surface and has a south dipping gradient at approximately 4.5 feet per mile. This gradient forces the direction of water flow to the south. See Fig. 6

for water gradient contours. In general, the ground-water in this region occurs under confined conditions, because clay has reduced the vertical permeability. (Wilson, 1981)

Ground-water moves southeastward beneath the West Mesa area, eventually converging with the water in the southern Mesilla Valley. Ground-water discharge occurs throughout both areas as drain flow to the river and evapotranspiration. Large surface-water irrigation allotments increase ground-water recharge, which improves the shallow ground-water quality neighboring these areas. Shallow ground-water discharges to drains which flow into the Rio Grande.

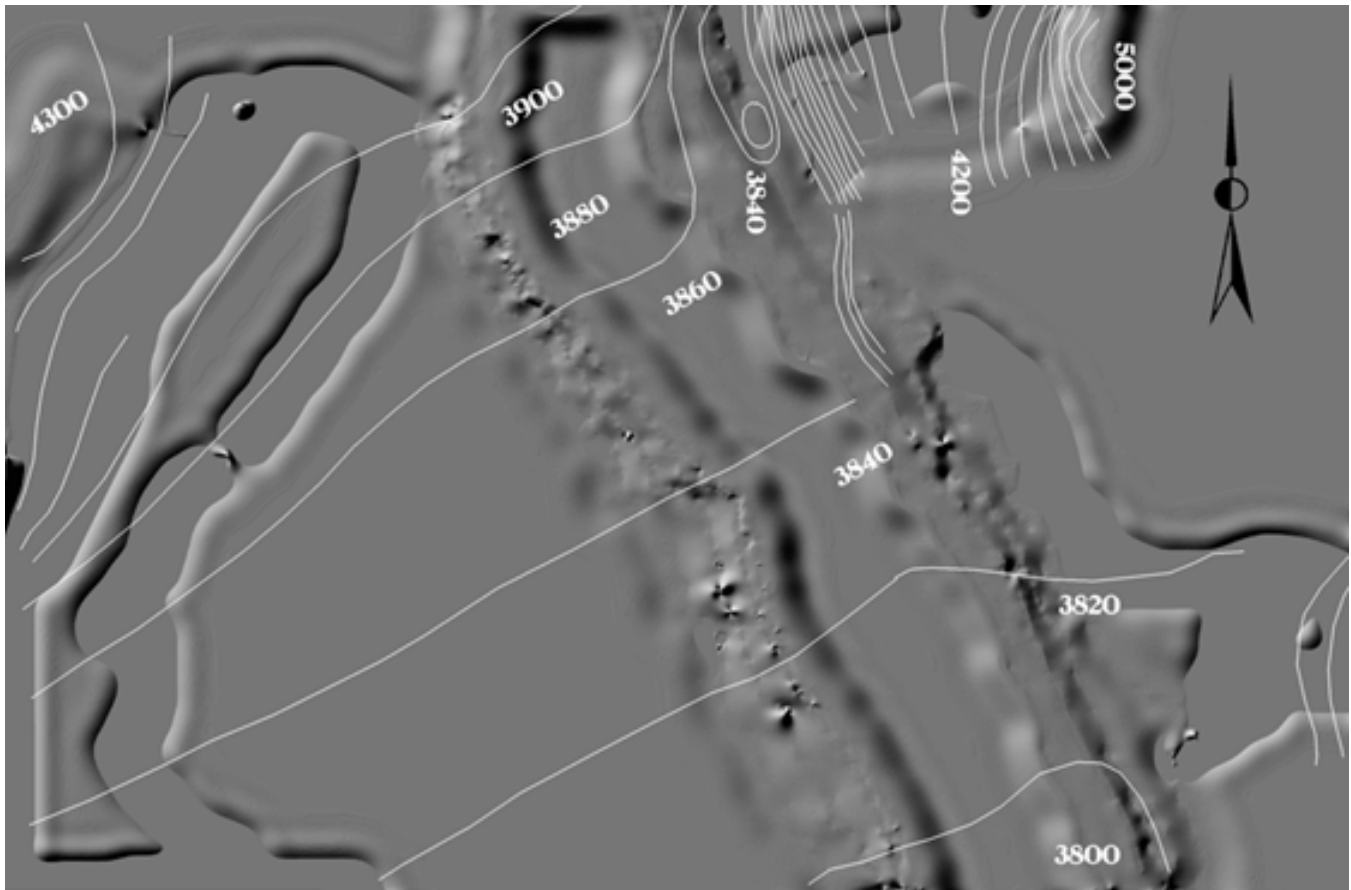


Fig. 5. Water gradient vector map.

Biomass Changes

We have found from the water quality study done in the southern Mesilla Valley that there are perhaps several factors contributing to the high levels of dissolved- solids in water samples. We wanted to determine whether the landfill could be the source. Our objective was to determine if poor water quality could be related to changes in vegetation vigor. The method would be to manipulate color infrared imagery to show changes in vegetation health.

We had a limited amount of color infrared aerial photography, removing our ability to map changes over the entire operating period of the site. A decision was made to look at imagery collected a short time after the peak dumping or growth period of the landfills life cycle. This peak period occurred during 1980. We chose coverage shortly after that, 1984 and 1986. Choosing coverage during this period would

ensure that if any migration of contaminants had occurred, it would have had time to spread to nearby vegetation. Growth of the site had continued for these years as well, but was overall in general decline.

Two 1:58,00 scale, color infrared (CIR) images were scanned. The scanning process yielded 3 files per image, a red, green, and blue intensity image. These two CIR images were studied very carefully for signs of vegetation decay. Then each pair of bands were subtracted. Subtraction is primarily a way to discover differences between images. Subtracting one image from another effectively removes from the difference image all features that do not change, while highlighting those that do. It is very important when subtracting vegetation images they must be very close in acquisition date, acquisition geometry, and illumination. If these parameters are not consistent there will be entirely too much variation in pixel value, and the subtraction will produce false changes in the resultant image.

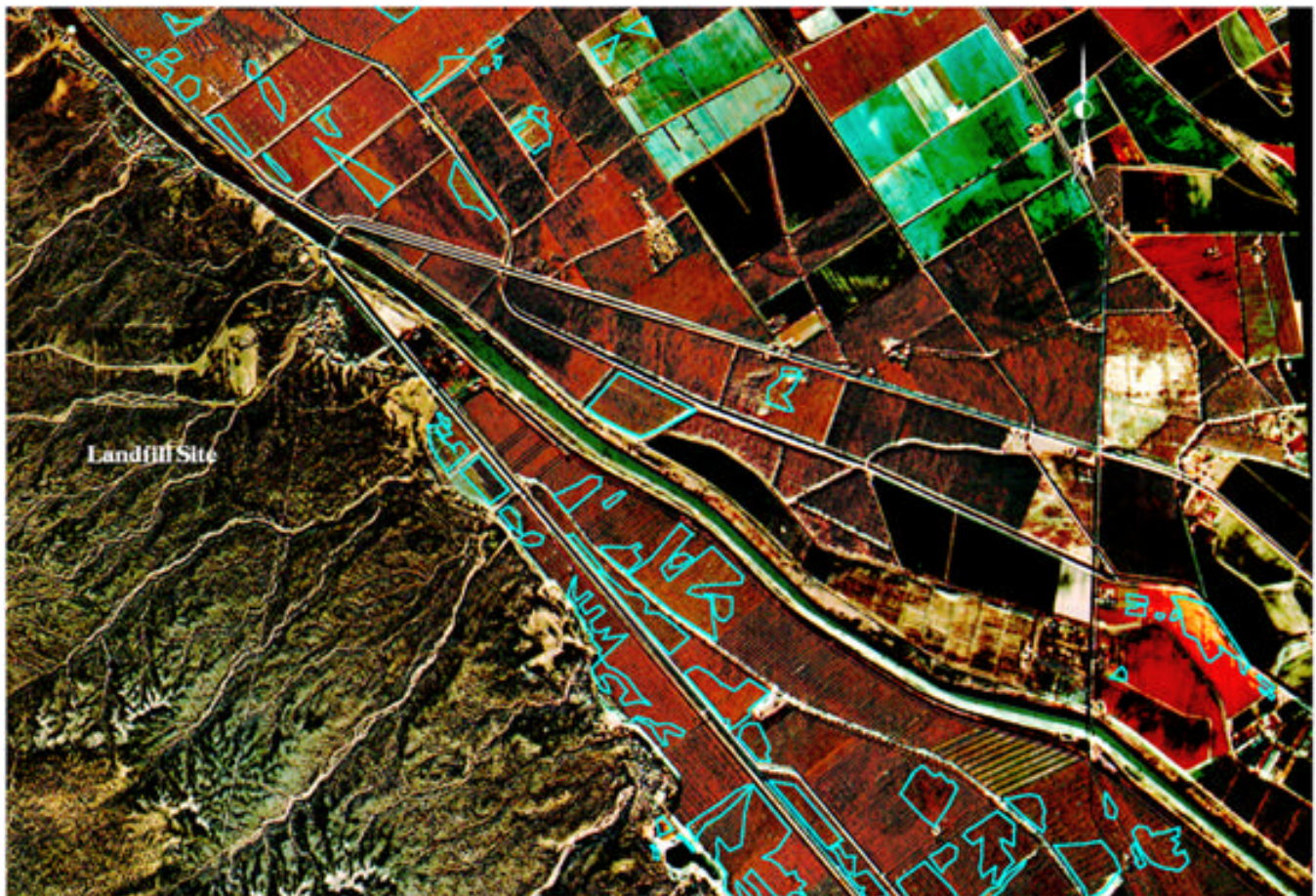


Fig. 6. Image difference between 1984 and 1986. Color IR images of the Las Cruces landfill. The cyan vector delineates areas of vegetation stress. Image scale is 1:58,000 ft.

The change image was examined to detect areas of vegetation which showed initial stress (dark magenta or pink), areas of advanced stress (white or pink-purple), and areas of dead or defoliated vegetation (yellow, blue, and green). All three levels of decay were delineated into one vector. Figure 6 depicts the cyan vector overlaid on the CIR image which encompasses areas of vegetation stress. Now that there was some evidence of vegetation stress and it was mapped out, it could be merged with

hydrography vectors of the area. The merged vectors would reveal trends in vegetation stress and local water flow in and around the landfill site. Figure 7 shows hydrology and vegetation stress vectors merged. The vectors show that south and east from the landfill there are several areas of stressed vegetation. The stressed vegetation shows a migration tendency southward along the west side of the Santo Tomas Drain. This migration coincides with the shallow ground-water discharge patterns, which discharge to drains and ultimately flows into the Rio Grande.

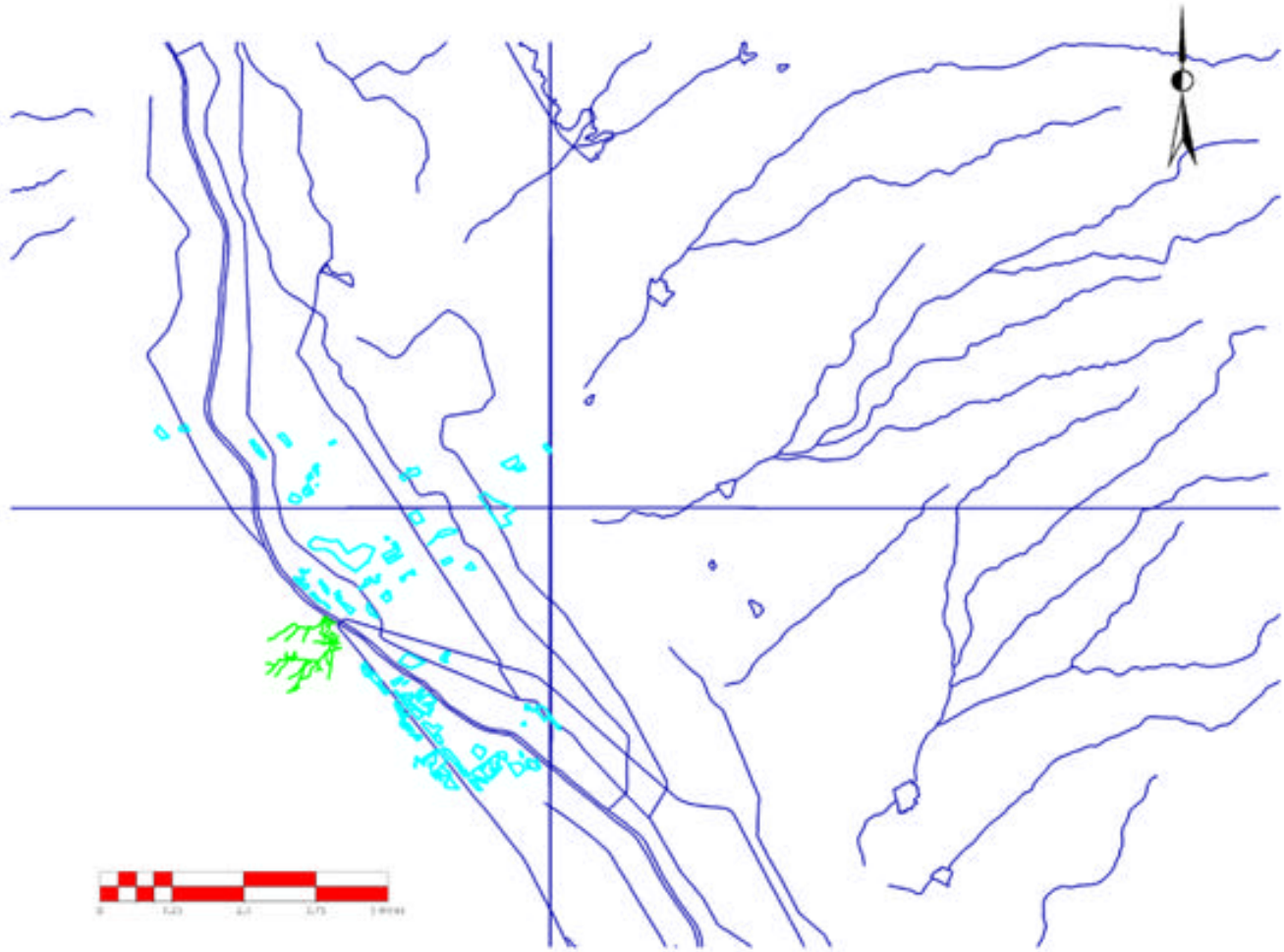


Fig. 7. Hydrography vector in dark blue merged with vegetation stress vector in cyan. Landfill drainage is in green.

Summary

Our objective was to characterize the Las Cruces Municipal Landfill using aerial photography, digital imagery and GIS. Using image animation and psuedo-color band compositions we were able to detect significant changes in topography and hydrography and to map these changes using GIS. Mathematically manipulating color infrared imagery allowed us to assess potential contamination routes and tendencies from the site towards ground water. Map data of soil and water were fused to provide additional site information.

A good preliminary characterization and analysis has been completed with the outcome being the Las Cruces Municipal Landfill is potentially a threat to the local water table. Monitoring wells for leachate and drinking water should be established. A total of 6 would be adequate, one of each kind located on the southeast, south, and northwest faces. Several wells south along the Santo Tomas Drain would also be beneficial. Soil samples should be taken over a uniform area surrounding, and including the site. Future characterization work would include sub-surface characterization using variograms or Kriging models for subsurface contamination (plume detection/migration). A 3-D model should be created for combining the surface and sub-surface data.

Acknowledgments

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